

SHORT REPORT

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LUMINAIRE LAYOUT: DESIGN AND IMPLEMENTATION

A.J. Both

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Department of Agricultural and Biological Engineering  
Cornell University, Riley-Robb Hall, Ithaca, NY 14853-5701, USA

The following information was presented during the discussion regarding guidelines for PAR uniformity in greenhouses. The data shows a lighting uniformity analysis in a research greenhouse for rose production at the Cornell University campus. The luminaire layout was designed using the computer program Lumen-Micro (Lighting Technologies, Inc., Boulder, CO). A total of 48 luminaires (General Electric, model GHL Low Profile, 400 Watt HPS) were installed (Figure 1). After implementation of the design, accurate measurements were taken in the greenhouse and the uniformity analysis for both the design and implementation were compared (Table 1). A study of several supplemental lighting installations resulted in the following recommendations:

- Include only the actual growing area in the lighting uniformity analysis (i.e., exclude any areas, such as walkways, at the edges of the growing area).
- For growing areas up to 20 m<sup>2</sup>: Take 4 measurements per m<sup>2</sup>, i.e., one measurement in the center of each 0.25 m<sup>2</sup> (0.5 m by 0.5 m).
- For growing areas above 20 m<sup>2</sup>: Take 1 measurement per m<sup>2</sup>, i.e., one measurement in the center of each m<sup>2</sup> (1 m by 1 m).
- Use one of the Uniformity Criteria (Table 2) and frequency graphs (Figure 2) to compare lighting uniformity amongst designs.
- Design for a Uniformity Criterion of at least 0.75 (preferably at least 0.90) and the fraction within ± 15% of the average PAR value should be close to 1 (Figure 2).

TABLE 1. Lighting uniformity analysis for the rose greenhouse at Cornell.

	DESIGN	IMPLEMENTATION
Average	107	97
Average ± 15%	91 - 123	82 - 112
Min - Max	49 - 159	28 - 167
Standard Deviation	30	33
Growing Area (m <sup>2</sup> )	118	118
Number of Data Points	220	128
Number of Measurements m <sup>-2</sup>	1.9	1.1
Number of Luminaires	48	48
Number of Luminaires m <sup>-2</sup>	0.4	0.4
	(Recommendation)	
Min/Avg	0.46 (≥0.80)	0.29 (≥0.80)
Min/Max	0.31 (≥0.70)	0.17 (≥0.70)
Uniformity Criterion 1	0.77 (≥0.75)	0.72 (≥0.75)
Uniformity Criterion 2	0.72 (≥0.75)	0.66 (≥0.75)

**TABLE 2** Definitions of two Uniformity Criteria (UC)

$$UC\ 1 = 1 - [(\sum |Y_i - Y_{ave}|) / (n \cdot Y_{ave})]$$

$$UC\ 2 = 1 - CV = 1 - [\sqrt{(\sum (Y_i - Y_{ave})^2 / (n - 1))} / Y_{ave}]$$

where:  $Y_i$  = PAR reading at location  $i$   
 $Y_{ave}$  = Average PAR reading over the growing area  
 $n$  = Number of PAR readings over the growing area  
 $CV$  = Coefficient of variation

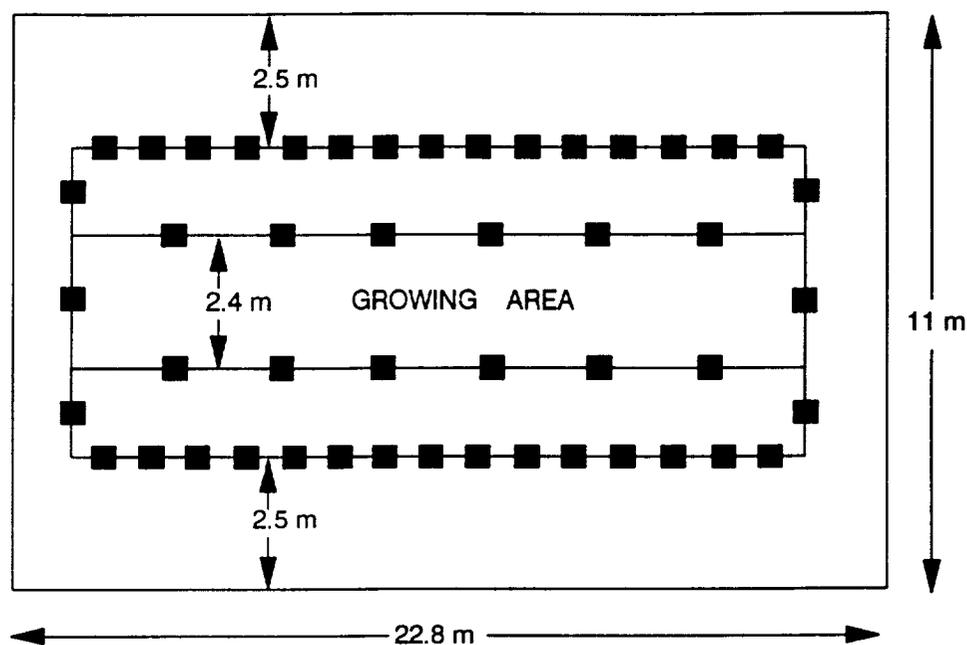


Fig. 1. Luminaire layout for a rose greenhouse at Cornell. Additional dimensions are: The bottom of the reflectors is located 1 m above the top of the canopy and the top of the canopy 1.95 m above the floor. The walkway along the left side wall is 1.45 m wide and the one along the right side wall 2 m. The distance between the luminaires in the top and bottom row is 1.22 m and the same distance in the center rows is 2.76 m. The distance between the top row and the top center row is equal to the distance between the bottom center row and the bottom row and is 1.8 m. The distance between the luminaires in the left and right columns is 2 m. The center luminaires of the left and right columns are positioned directly underneath the ridge of the greenhouse. The left most luminaire on the bottom row is positioned 2.5 m from the left side wall and also 2.5 m from the bottom side wall.

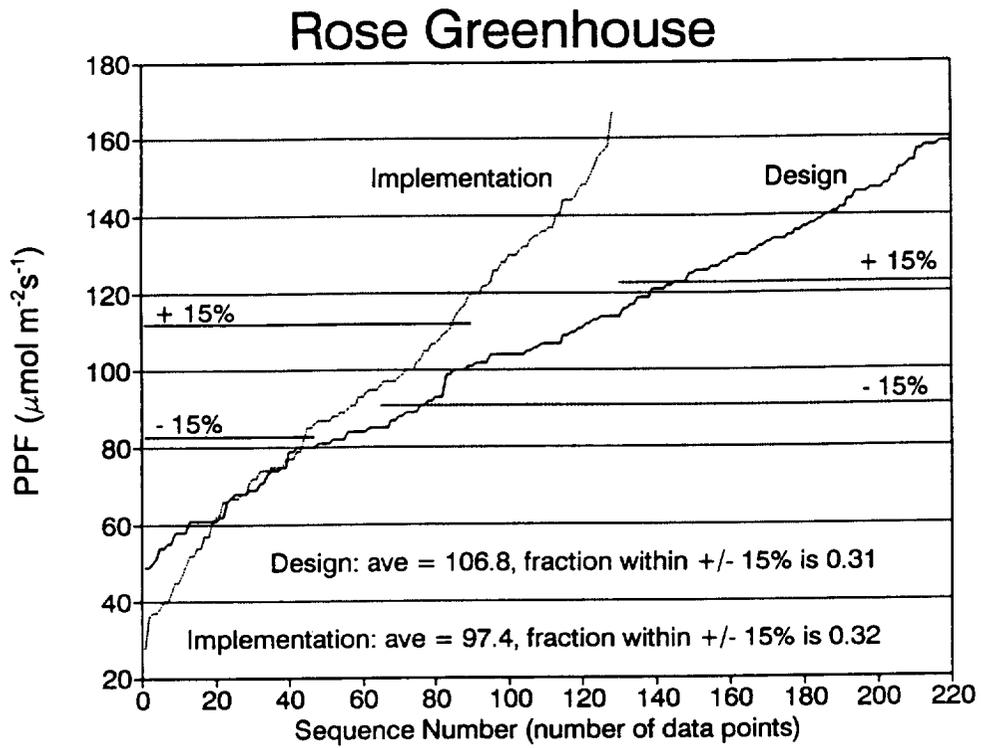


Fig. 2. Frequency graph for a rose greenhouse at Cornell.

#### REFERENCE

Albright, L.D. and A.J. Both (1994) Comparison of luminaires: efficacies and system design. Listed elsewhere in this publication.

